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Preliminary Evaluation of the Kaiser View™ Display System

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U.S. Army Research Institute
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14. ABSTRACT *(Maximum 200 words)*:

An evaluation of the prototype Kaiser Electronics VIEW™ Display System was conducted in conjunction with a study of the Army Tactical Command and Control System (ATCCS) during the first week of March 1998 at the request of the U.S. Army Aviation Center Directorate of Training, Doctrine and Simulation. The evaluation is based on responses of first-time users in a command and control environment. A questionnaire was developed to assess user impressions relating to a range of human factors aspects of the prototype helmet display system. This report contains a brief description of the evaluation method and findings. The responses indicate that the system is feasible as a tactical command and control display in a ground-based installation. The display system appears to have no disqualifying attributes. The utility of the display would be improved with an increase in display spatial resolution.

15. SUBJECT TERMS

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PRELIMINARY EVALUATION OF THE KAISER VIEW™ DISPLAY SYSTEM

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PRELIMINARY EVALUATION OF THE KAISER VIEW™ DISPLAY SYSTEM

Introduction

During discussions between Kaiser Electronics and the U.S. Army Aviation Center USAAVNC Directorate of Training Doctrine and Simulation (DOTDS), Kaiser Electronics agreed to make a prototype VIEW™ Display System[1] available for evaluation in an Army Aviation command and control environment. A decision was made to conduct the evaluation in conjunction with the Army Tactical Command and Control System (ATCCS) study that was scheduled for the first week of March 1998. The Army Research Institute (ARI) Rotary Wing Aviation Research Unit (RWARU) was requested by DOTDS to assist in the design and conduct of the evaluation. A questionnaire was developed to assess user impressions relating to a range of human factors aspects of the prototype helmet display system. This report contains a brief description of the evaluation method and findings.

The VIEW™ Display System evaluation was introduced into the ATCCS study with only a few days preparation time. The time constraints precluded the development of detailed human factors, training effectiveness, or performance enhancement measurement. The short preparation time available did not allow for pilot testing or refinement of the questionnaire. It was also recognized that the system was prototypic and, therefore, would not be appropriate for introduction into the simulated command and control system of the exercise. Therefore the helmet display was interfaced with the ATCCS suite only as a display monitor in the brigade Tactical Operations Center (TOC).

Method

Apparatus

The prototype system evaluated is based on a Kaiser Electro-Optics Inc. ProView™ Model PV-30 helmet mounted display integrated with Kaiser Electronics View™ video formatting and switching systems. The PV-30 is a lightweight helmet-mounted system with dual miniature color liquid crystal displays (LCD). It provides a total 30° horizontal by 22.5° vertical field of view with 100% overlap of the two video channels. Spatial resolution is rated by the manufacturer at 2.25 arcmin, brightness at 25 footlamberts, and contrast ratio at 25:1. Each LCD display is collimated (non pupil forming) in a 640 X 480 pixel format. Calculated spatial resolution is 2.81 arcmin per pixel pair (30 X 60 / 640). Eye relief is stated to be 50mm. Horizontal scan rate is 31.5 kHz and vertical scan rate is 60 Hz. The individual display units are fully occluded.

The helmet is constructed as a skeletonized semi-rigid plastic modular unit with internally mounted suspension that provides left and right circumferential adjustment and a center depth adjustment by means of ratcheting straps. The shell is an assembly of modules that provide partial coverage of frontal, temporal and occipital areas. The LCD display units mount

[1] VIEW is an acronym for Virtual Interactive Enhanced Workstation

together on the front of the helmet. A rotary knob on the upper frontal surface of the helmet provides vertical adjustment of the displays. A sliding coupling provides fore and aft adjustment. A detented pivot allows adjustment of the angle of the displays relative to the user's face and allows the displays to be flipped up for unobstructed viewing of the ambient environment. There are independent adjustments of the lateral positions of the LCDs that effect a means for setting interpupillary distance. Electrical connections are bundled into a single cord that attaches at the base of the occipital shell module. Connectors are provided on the temporal shell modules for optional microphone input and audio output to earphones. A knob mounted near the electrical cord can be turned to adjust display brightness. The helmet system weighs approximately 0.8 Kg (1.76 lb).

The helmet display system is interfaced to a PC-based processor that manages video source scan conversion, output scan conversion, display windows for multiple video sources, head tracking, video source switching and mapping video windows in virtual space and pan and zoom functions within windows. The system will accept up to six video sources (expandable by adding processing cards) and organizes these in a user programmable array within a 1280 X 1024 pixel MS-Windows environment. Video inputs may be VGA, SVGA, RS-170, NTSC, RS-343 or RGB formats in any combination. Switching among video sources and panning and zooming within a video source can be accomplished by head motion (head tracker), keyboard entry (arrow keys) or mouse inputs. Head tracking is performed by a Polhemus™ three axis electromagnetic position sensing system. The signal source was mounted on the helmet with hook and loop tape and the sensor placed on any proximate horizontal surface.

Participants

Seventeen individuals who were participants in or visitors to the brigade TOC during the ATCCS study served as participants in the VIEW™ Display System evaluation. Five participants were experienced scientists or engineers, 10 were experienced Army aviation officers, and two were foreign aviators serving as liaison officers. All participants were knowledgeable about (a) Army aviation command and control doctrine and tasks and (b) the function of the digital systems available in the simulated ATCCS.

Procedure

Participants were asked to don the head-mounted VIEW™ Display, perform the necessary adjustments, and view the input from a variety of digital workstation displays available in a simulated ATCCS. The simulated ATCCS, located at the Aviation Test Bed (ATB), Fort Rucker, Alabama, was equipped with many of the digital systems developed for use in future ATCCSs. The digital systems available in the simulated ATCCS are listed below:

- All Source Analysis System (ASAS),
- Joint Surveillance Target Attack Radar System (JSTARS),
- Maneuver Control System/Phoenix (MCS/P),
- Advanced Field Artillery Tactical Data System (AFATDS),

- Aircraft and Missile-Defense Workstation (AMD W/S),
- Forward Area Air Defense Engagement Operation (FAADEO),
- Combat Service Support Control System (CSSCS), and
- Unmanned Aerial Vehicle (UAV) video display.

After having completed the above tasks, each participant completed the six-page questionnaire shown in Appendix A. The items on the questionnaire were designed to assess participants' judgments about the following attributes of the VIEW™ Display and related topics:

- participants' exposure (time helmet worn and type inputs viewed),
- speed and ease of performing helmet adjustments,
- helmet weight and weight distribution,
- helmet stability (on head),
- image quality,
- selection of display input,
- control of field of view (zoom),
- effect of VIEW™ Display on task difficulty,
- other indicators of the VIEW™ Display's utility in a TOC,
- simulator sickness symptoms,
- judged utility of the VIEW™ Display for use in a ground-based and an airborne TOC, and
- recommended design improvements.

Findings

The VIEW™ Display was operated 24 hours per day during the execution of the exercise. During this time there were only minor system failures, some of which may have been operator induced. At least one other was attributable to a failure outside the system (faulty signal cable). On the third day of operations it was necessary to shut the system down completely in order to reinitialize. This was probably due to an accumulation of unneeded data in memory resulting in increased processing times. System restart too approximately ten minutes. This prototype was generally reliable in operation.

The following sections describe the participants' responses to the questionnaire items. The discussion of responses is organized by topic so, in some cases, several questionnaire items are discussed together. Readers who want more detailed information about responses to the questionnaire items are referred to Appendix B, which contains a comprehensive tabulation of responses for every item. Simple descriptive and inferential statistics are included for appropriate items. The cover sheet for Appendix B describes its content and organization.

Participants' Exposure

Participants' assessments of the VIEW™ Display must be interpreted in light of the amount of time they wore the VIEW™ Display and the imagery they viewed. Accordingly, the

questionnaire contained items that asked participants to indicate the amount of time they wore the VIEW™ Display, the amount of time they spent viewing active workstation imagery and the types of workstation imagery they viewed.

On average, the participants wore the VIEW™ Display for 22.5 min and viewed active workstation imagery for 18.3 min. One participant wore the VIEW™ Display for only 8 min; 5 wore the display for 10 min; 5 wore the display for 15 min; and the remaining 6 participants wore the display for 20 min or more. Participants viewed active workstation imagery during most of the time they wore the VIEW™ Display. Fifteen participants spent at least 70% of the time viewing workstation imagery; the remaining three participants spent between 50% and 60% of the time viewing workstation imagery.

Not all of the ATCCS systems were operational at the time the participants wore the VIEW™ Display, so participants differed in their opportunity to view the various ATCCS displays. All participants viewed at least two different ATTCS displays; 15 participants viewed 3 or more ATCCS displays; and 11 participants viewed 4 or more ATCCS displays. On average, participants viewed 4.4 different ATCCS displays during the time they wore the VIEW™ Display. Figure 1 shows the number of participants who viewed each display that was present in the ATCCS during the time the VIEW™ Display evaluation was conducted. All participants viewed the ASAS display and 16 participants viewed the MCS/P display. The UAV video was viewed by 11 participants, and the remaining ATCCS displays were viewed by 8 or fewer participants.

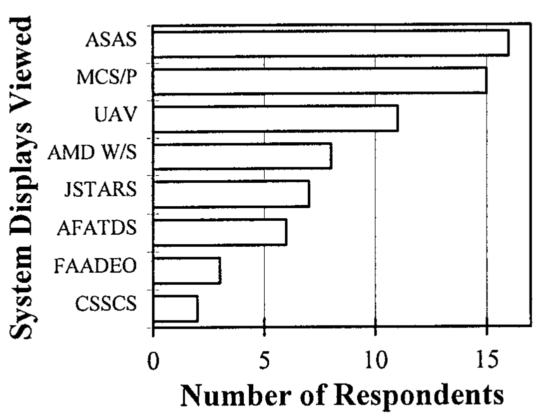

Figure 1. Number of participants who viewed each type system display present in the simulated TOC at the time the VIEW™ Display evaluation was conducted.

A diverse set of map features, tactical symbols, and alphanumeric characters are portrayed on the ASAS display and the MCS/P display. For this reason, the ASAS imagery and the MCS/P imagery represent demanding tests of the VIEW™ Display's utility for viewing a wide range of different types and sizes of features. In particular, it is certain that every participant was exposed to displayed features that are among the most difficult to discriminate.

Table 1 shows the number and percentage of individuals who participated in each of 10 activities while wearing the VIEW™ Display (responses to Items 5 and 6). No participant was actively engaged in command and control activity at the time the VIEW™ Display was worn. However, at least two participants were engaged in each of the other activities during the time they wore the VIEW™ Display. Every participant selected different workstation inputs by moving the head, and 16 participants used head movements to zoom-in and zoom-out on a display image. Input selection and zooming with a mouse were performed by 15 participants and 12 participants, respectively. Fewer than one-half of the participants engaged in the remaining activities. For this reason, only a small number of cases are available to assess the VIEW™ Display under offset viewing conditions (8 participants), very low ambient illumination (6 participants), or high ambient illumination (2 participants). Similarly, only 6 participants attempted to interact with another person about a feature depicted on the VIEW™ Display.

Table 1.

Number and percentage of participants who engaged in each type activity while wearing the VIEW™ Display.

	PARTICIPANTS	
TYPE ACTIVITY	N	%
Select different workstation displays by moving head	17	100
Zoom-in on a workstation display by moving head	16	94
Select different workstation displays by moving a mouse	15	88
Zoom-in on a workstation display by moving a mouse	12	71
Offset viewing (display is located left or right of frontal plane)	8	47
View display in low ambient illumination	6	35
Interact with another person about a specific displayed feature	6	35
View display while moving about the TOC	3	18
View the display in high ambient illumination	2	12
View display while engaged in command and control activities	0	0

Helmet Adjustment, Weight, and Stability

Speed and ease of helmet adjustments. The questionnaire contained items that asked participants to (a) rate the ease with which each type of adjustment was accomplished and (b) estimate the time required to complete each type of adjustment. Ratings and time estimates were provided for each of the four types of adjustments listed below:

- adjust the helmet to fit the head,
- adjust the displays in the longitudinal plane (fore and aft),
- adjust the displays in the vertical plane, and
- adjust the lateral distance between the displays (interpupillary distance).

Participants rated ease of adjustment using a 5-point scale that varied from *very easy* (rating of 1) to *very difficult* (rating of 5). The intermediate scale value (rating of 3) was labeled *moderately easy*. The mean rating for the four adjustments varied from 1.2 to 1.6. Only two participants selected a rating value higher than 2. One participant indicated that the interpupillary adjustment was only *moderately easy* (rating of 3); one participant indicated that the longitudinal adjustment was *moderately difficult* (rating of 4).

Participants reported that little time was required to complete the helmet adjustments. The median adjustment time was 1 min or less for each of the four types of adjustments listed above. Only two participants reported an adjustment time of 3 min or more. The mean time to adjust interpupillary distance was larger (2.2 min) that the mean time for the other adjustment (slightly less than 1 min). However, the difference in means was due entirely to the difficulty that one participant encountered in adjusting interpupillary distance. All other participants indicated that adjusting interpupillary distance was no more time consuming than the other three adjustments.

Item 9 asked participants if they encountered any difficulty adjusting the displays to a position where the display images were in clear focus. Nine of the 15 participants who responded to this item indicated that they did <u>not</u> encounter difficulty adjusting the displays to achieve a clear focus. The interpretation of the five affirmative responses to this item is unclear. That is, it is uncertain whether these participants were indicating that (a) the adjustment was difficult to perform, or (b) it was not possible to achieve a clearly focused image. Responses to other questionnaire items favor the latter interpretation.

<u>Weight and weight distribution</u>. Excessive weight and unequal weight distribution are common problems for head-mounted displays. The questionnaire included items designed to assess participants' judgments about the acceptability of both the weight and the weight distribution of the VIEW™ Display.

Item 10 asked participants if they encountered any difficulty adjusting the helmet so that the weight was about evenly distributed on the head. Only 3 participants reported that unequal weight distribution was a problem. All 3 of the participants reported that the helmet remained slightly front heavy even after the adjustments had been completed.

Item 11 required participants to use a 5- point scale to rate the severity of four different types of discomfort. The rating scale varied from *no discomfort* (rating of 1) through *moderate discomfort* (rating of 3) to *severe discomfort* (rating of 5). The four types of discomfort that were rated are listed below:

- general discomfort where the helmet touched the head,
- discomfort at only a few spots on the head (hot spots),
- neck discomfort from weight on head, and
- shoulder discomfort from weight on head.

The results of the ratings are summarized in Figure 2. The data are in percentage values because not all participants rated every type of discomfort. However, 15 or more participants rated each type of discomfort. Most participants reported that they experienced *no discomfort* or only slight discomfort (rating of 2) for each of the four types listed above. Approximately 19% of the participants reported experiencing *moderate* general head discomfort, and about 13% reported experiencing *moderate* neck discomfort from the weight of the helmet (see Figure 2). Only 1 participant reported experiencing *moderate discomfort* from hot spots on the head and 1 participant reported experiencing *moderate* shoulder discomfort caused by the weight of the helmet. No participant rated any type of discomfort more severe than *moderate*. Slight discomfort (rating of 2) from hot spots on the head was reported by nearly one-half of the participants. Slight neck discomfort (rating of 2) was reported by about one-third of the participants. Fewer than one-fourth of the participants reported experiencing slight (rating of 2) head discomfort (general) or shoulder discomfort. No participants produced ratings of 4 or 5 for any type of discomfort.

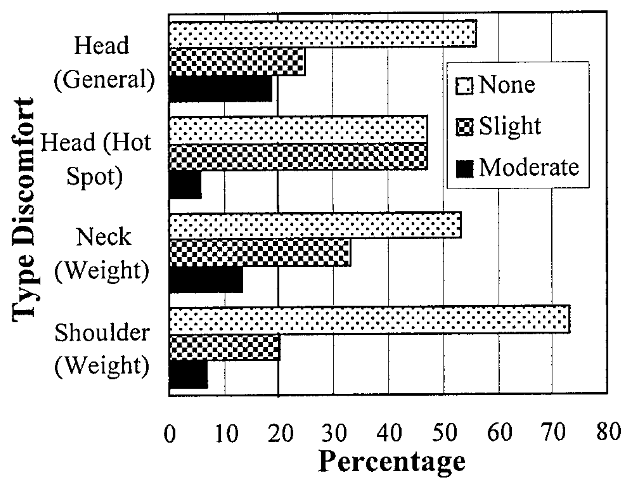

Figure 2. Type and severity of discomfort experienced while wearing the VIEW™ Display.

Item 31 asked participants to identify design changes that, in their opinion, would increase the usability or utility of the VIEW™ Display. Only 1 participant indicated that reducing the VIEW™ Display's weight was a desirable design change.

These data indicate that the VIEW™ Display can be worn for as much as 90 minutes with little or no discomfort. It cannot be concluded from these data that the VIEW™ Display can be or cannot be worn for longer periods of time without causing discomfort that is severe enough to degrade users' performance.

Helmet stability. Three questionnaire items addressed the stability of the helmet on the head. Item 12 asked participants if the cable attached to the rear of the helmet sometimes caused

the helmet to move on the head when the head was moved. Ten of the 17 participants (about 59%) answered affirmatively, indicating that the cable sometimes caused the helmet to move on the head.

Item 13 asked participants to rate the magnitude of the helmet movement resulting from lateral head rotation, vertical head rotation, and fore/aft head movement. Participants rated magnitude of helmet movement on a 5-point scale that varied from *no movement* (rating of 1), through *slight movement* (rating of 3), to *large movement* (rating of 5). The mean ratings for lateral, vertical, and fore/aft movement were 2.3, 2.3, and 1.8, respectively. The percentage of participants who selected each of the rating values is shown in Figure 3 for each type of head movement. No participant selected a rating value of 5 and only one participant selected a rating value of 4. Nearly identical rating value distributions were found for vertical and lateral head rotation. However, the distribution of ratings indicates that slightly less helmet movement results from fore/aft head movement than from either vertical or lateral head rotation. When rating the helmet movement resulting from fore/aft head movement, about 69% of the participants selected a rating value less than 3 (small movement). In contrast, about 47% of the participants selected a rating value less than 3 when rating the magnitude of helmet movement resulting from vertical head rotation and lateral head rotation.

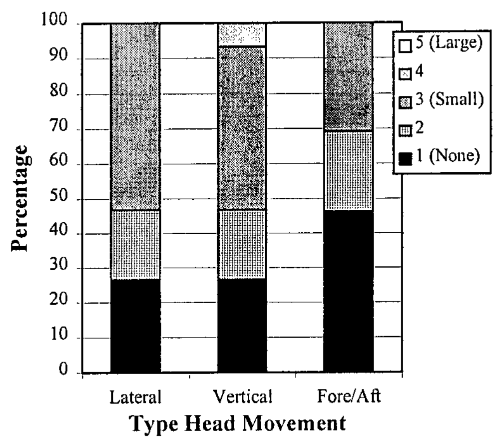

Figure 3. Participants' ratings of helmet movement as a function of type of head movement.

Participants used a 5-point scale to rate their agreement with the statement I *was able to move my head as fast as I wanted without the helmet moving on my head.* The rating scale varied from *strongly agree* (rating of 1) to *strongly disagree* (rating of 5); the midpoint was *neutral* (rating of 3). The mean and median of the participants' ratings were 2.8 and 2.0, respectively. Five participants indicated that they *disagreed* ($\underline{n}$ = 4) or *strongly disagreed* ($\underline{n}$ = 1) with the statement. The remaining participants indicated that they *agreed* with the statement ($\underline{n}$ = 9) or were *neutral* ($\underline{n}$ = 3). No participant indicated that they *strongly agreed* with the statement.

Although most participants reported some movement of the helmet, the data presented above provide no evidence that helmet movement (i.e., lack of helmet stability) is a serious problem in the ground-based environment in which the evaluation was conducted.

Image Quality

Acquiring valid information about image quality is made difficult by the fact that the terms used to describe image quality are not universally understood. Display resolution is among the most poorly understood image-quality descriptors. Individuals with no training on display-resolution measurement tend to assume that poor resolution is the cause of any image that is difficult to see. For this reason, an attempt was made to draft questionnaire items that used as few image-quality terms as possible.

Resolution and size of viewing area. For all tactical situation displays, there is a competing need to see all or a large portion of the battle area and, at the same time, discriminate the alphanumeric characters, point features, and linear features that appear on the display. The "zoom" feature of the VIEW™ Display enables a user to zoom-in (magnify) on a feature until it is large enough to be discriminated and to zoom-out (de-magnify) in order to increase the size of the viewing area. Questionnaire items were drafted to determine if the size of the viewing area was adequate when different types of features were large enough to be discriminated. Participants were asked to indicate their agreement with each of the following statements:

- In order to discriminate a character (letter or number), I often had to zoom-in on the character more than I wanted.
- In order to discriminate a point symbol, I often had to zoom-in on the point symbol more than I wanted.
- In order to discriminate a linear symbol, I often had to zoom-in on the symbol more than I wanted.

Participants used the 5- point scale described earlier to rate their agreement with each of the three statements listed above (1 = *strongly agree*, 2 = *agree*, 3 = *neutral*, 4 = *disagree*, and 5 = *strongly disagree*). Participants' responses are summarized in Figure 4.

Participants were nearly unanimous in their agreement that they had to zoom-in more than they wanted in order to discriminate alphanumeric characters. The mean and median ratings were 1.5 and 2.0, respectively. Sixteen participants (94%) indicated that they *agreed* or *strongly agreed* that it was necessary to zoom-in too far in order to discriminate alphanumeric characters.

The responses for point symbols were similar to those for alphanumeric characters. The mean rating was only slightly higher for point symbols (1.9) than for alphanumeric characters (1.6); the median ratings were the same (2.0). Twelve participants (71%) indicated that they *agreed* or *strongly agreed* that it was necessary to zoom-in too far in order to discriminate point symbols. The remaining 4 participants selected the *neutral* rating.

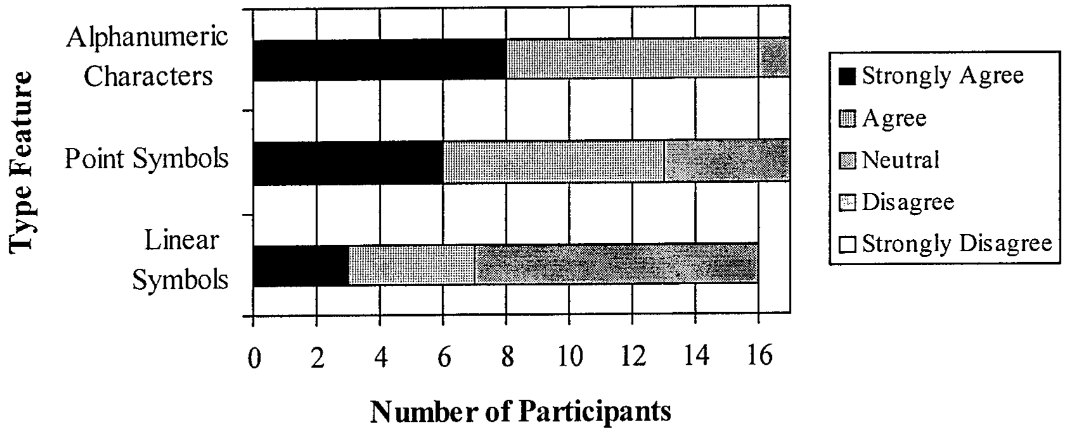

Figure 4. Participants' agreement that it was necessary to zoom-in too far in order to discriminate alphanumeric characters, point symbols, and linear symbols.

The responses for linear symbols were substantially different from those for alphanumeric characters and point symbols. The mean and median ratings were 2.5 and 3.0, respectively. Only 7 participants (41%) indicated that they *agreed* or *strongly agreed* that it was necessary to zoom-in too far in order to discriminate linear symbols. However, only one participant indicated that he *disagreed* with the statement. Nine participants (53%) selected the *neutral* rating. These responses suggest that there is less requirement to sacrifice viewing area to discriminate linear symbols than either alphanumeric characters or point symbols.

Participants also were asked to indicate their agreement with the statement: When *characters and symbols were large enough to be legible, I could not see as much of the total display as I wanted to see*. This item yielded nearly the same response distribution as the item aimed specifically at linear symbols. Although only two participants *disagreed* or *strongly disagreed* with this statement, nine participants (53%) selected the *neutral* alternative. When the type of feature is not specified, participants apparently responded in terms of the most easily discriminated type of features (viz., linear symbols).

A final comment about display resolution is that 7 of the 13 participants who recommended design improvements identified increased resolution as a design improvement that would increase the utility and usability of the VIEW™ Display.

Sharpness of image. Items 20, 21, and 22 asked participants about the sharpness of the VIEW™ Display. Item 20 asked participants if the displayed image appeared to be in sharp focus. Item 21 asked participants if image sharpness was the same over the entire display surface; Item 22 asked participants if image sharpness remained stable over time.

Twelve participants (71%) indicated that the displayed images did *not* appear to be in sharp focus. The same number of participants indicated that the image sharpness was uniform

across the entire display surface. Fifteen participants (88%) indicated that the image sharpness did *not* change during the time they wore the VIEW™ Display.

Contrast. Participants used the 5-point rating scale described earlier to rate their agreement with the statement: Objects *on the display were difficult to discriminate because of inadequate contrast.* The mean and median ratings were 3.3 and 3.0, respectively. Only three participants (18%) indicated that they *agreed* or *strongly agreed* with this statement. The remaining participants selected the *neutral* alternative (n = 7) or indicated that they *disagreed* or *strongly disagreed* with the statement (n = 7).

Color discriminability. The same 5-point rating scale was used by participants to rate their agreement with the statement: It *was sometimes difficult to discriminate the color of objects.* The mean and median ratings for this item were 3.6 and 4.0, respectively. Eleven participants (65%) indicated that they *disagreed* or *strongly disagreed* with the statement, and three participants selected the *neutral* response. These data indicate clearly that most participants encountered no difficulty discriminating colors on the VIEW™ Display.

Image aberrations. Participants were asked if the images were free of spatial distortions (Item 18) and color distortions (Item 19). Fifteen participants (88%) reported that the display was free of both spatial and color distortions. Fourteen of the 16 participants who responded to Item 23 (88%) indicated that they did *not* notice any type of video noise or other image aberrations that degraded quality of the display images. One participant, an engineer/scientist, reported "some aliasing and scintillation, especially through horizontal lines."

Effect of high ambient illumination and glare. Participants were asked if the image quality was degraded by high ambient illumination (Item 16) or glare (Item 17). The one participant who wore the VIEW™ Display in relatively high ambient illumination indicated that the image quality was ***not*** degraded by the highest level of ambient illumination experienced. Of the three participants who reported experiencing some glare, two indicated that the glare sometimes made it more difficult to discriminate displayed features (e.g., alphanumerics and symbols).

Selection of Display Input and Zoom

As stated earlier, the VIEW™ Display System is equipped with a head tracker that enables users to (a) select the input to be displayed on the VIEW™ Display by rotating the head and (b) zoom-in on an image (i.e., magnify the image) by moving the head fore and aft. The VIEW™ Display System also enables the user to accomplish the search and zoom functions with a mouse. Item 25 asked participants to rate the ease of selecting and zooming with head movements and with a mouse. The 5-point rating scale used by participants varied from *very easy* (rating of 1) through *moderately difficult* (rating of 3) to *very difficult* (rating of 5). The findings are summarized in Figure 5 and are discussed below.

It is clear from Figure 5 that participants believed that it was easier to select and zoom with a mouse than with head movements. About 65% of the participants indicated that it was

very easy or *easy* to select the display input with the head; all participants (100%) indicated that it was *very easy* or *easy* to select with a mouse. The difference between head movement control and a mouse control was even greater for the zooming function. About 37% of the participants indicated that it was *very easy* or *easy* to zoom with head movements; whereas, all of the participants (100%) indicated that zooming with a mouse was *very easy* or *easy*.

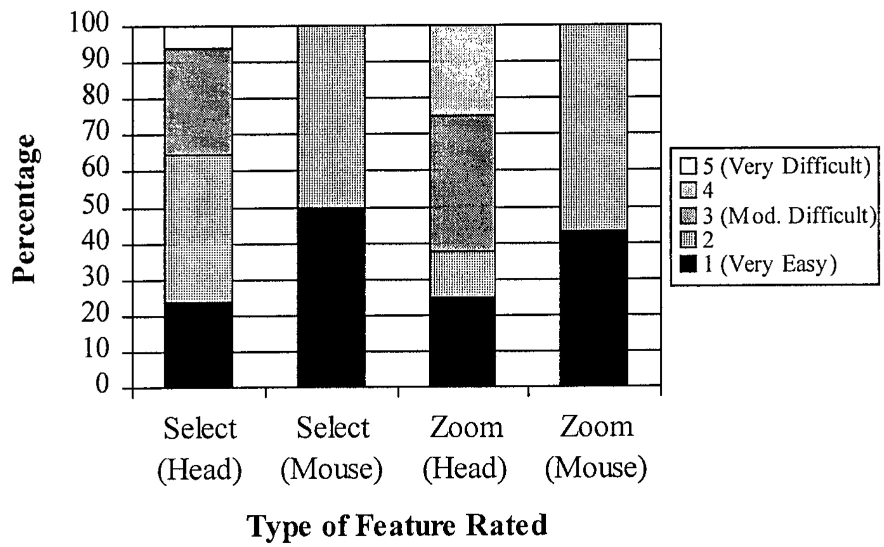

Figure 5. Participants' ratings of the ease of selecting the display input and zooming with head movements and with a mouse.

Although participants indicated that it was easier to select with a mouse than with head movements, their rating did not indicate that selecting with head movements is difficult enough to be a serious problem. Only one participant (5.9%) indicated that the difficulty level was higher than *moderately difficult* (rating of 3). Moreover, only one participant indicated an improved method for selecting display inputs would be an effective design improvement (response to Item 31).

For head movement control, the level of difficulty was reported to be higher for the zoom function than for the select function. Nearly two-thirds of the participants indicated that zooming with head movements was *moderately difficult* (38%) or *difficult* (25%). The high difficulty ratings for the zoom function may stem from the fact that the image becomes sensitive to small head movements when the user has zoomed-in on an image to the maximum. Three participants suggested that a method to stabilize highly magnified images (maximum zoom) would be a highly desirable design improvement (response to Item 31).

Effect on Task Difficulty

Item 26 required participants to indicate whether the VIEW™ Display makes selected information-processing tasks easier or more difficult than the displays that are now used in the

simulated ATCCS. The 5-point rating scale varied from *much easier* (rating of 1) through *about the same* (rating of 3) to *much more difficult* (rating of 5). Table 2 shows the tasks that were rated, the number of participants who rated each task, the mean rating, and the percentage of participants who selected each rating value. The median rating was the same (3.0) for all tasks, so it is not shown in Table 2.

Table 2.

Participants' ratings of the relative difficulty of performing selected information-processing tasks with the VIEW™ Display.

			Rating Scale Values				
INFORMATION PROCESSING TASKS RATED	N	Mean	1 Much Easier	2 Easier	3 About the Same	4 More Difficult	5 Much More Difficult
Obtain information quickly	13	3.2	0	23.1%*	38.5%	30.8%	7.7%
Convert data into information	12	3.2	0	16.7%	58.3%	16.7%	8.3%
Maintain situational awareness	12	3.2	0	33.3%	25.0%	25.0%	16.7%
Share information with other staff	11	3.4	0	27.3	27.3%	27.3%	18.2%

*The cell values are the percentage of participants who selected the corresponding rating-scale value.

Participants' ratings were quite similar for all four tasks. The mean ratings for the four tasks varied from 3.2 to 3.4, and the median rating was 3.0 for all tasks. No participant indicated that any of the four tasks was *much easier* to perform with the VIEW™ Display. There was no task for which more than one-third of the participants indicated that the task was *easier* (rating of 2) to perform. Conversely, there was no task for which more than 18% of the participants indicated that the task was *much more difficult* (rating of 5) to perform. For all tasks, the majority of participants indicated that task difficulty was *about the same* (rating of 3) or *more difficult* (rating of 4).

These data must be interpreted in light of the small amount of time the participants wore the VIEW™ Display. In effect, participants were asked to compare a system they had never used before with a system with which they were reasonably familiar. It is possible that with more practice, the participants would learn to use the VIEW™ Display more efficiently and, as a consequence, would rate its ease of use much higher. Alternately, greater wearing times may lead to increased discomfort.

Other Indicators of Usability in a TOC

Item 24 asked participants to rate their agreement with several statements about the VIEW™ Display's usability in a TOC. Participants used the 5-point rating scale described earlier to make their ratings. The responses to each of the items are discussed below.[2]

One item asked participants if the cable attached to the rear of the helmet constrained their freedom to move around the simulated ATCCS. Nearly 47% of the participants indicated that they *strongly agreed* (rating of 1) or *agreed* (rating of 2) with this statement. The remaining participants (54%) selected the *neutral* response (rating of 3). The fact that no participant indicated that they *disagreed* (rating of 4) or *strongly disagreed* (rating of 5) with the statement indicates that all participants believed that the cable attached to the helmet constrained their freedom of movement to some extent.

It was of interest to determine if participants could gain visual access to other information in the simulated ATCCS by looking under or to the sides of the VIEW™ Display. A questionnaire item asked participants to indicate their agreement with the statement: I *was able to view other things I needed to see in the TOC by looking under the display or to the left or right of the display.* The mean and median of the ratings were 2.7 and 2.0, respectively. Participants' ratings for this item varied widely. Nearly 53% indicated that they *strongly agreed* (rating of 1) or *agreed* (rating of 2) with the statement, and about 23% indicated they *disagreed* (rating of 4) or *strongly disagreed* (rating of 5) with the statement. The remaining 24% selected the *neutral* rating (rating of 3). The reasons for the large differences in participants' ratings are not known.

Because the VIEW™ Display images are collimated, it was of interest to determine if participants encountered problems in alternating their view between the display and objects in the room. Participants were asked to indicate their agreement with the statement: I *had trouble alternating my view between the displayed images and objects in the room.* Only one participant *strongly agreed* (rating of 1), and one participant *strongly disagreed* (rating of 5) with this statement. A larger and about equal percentage of participants indicated that they *agreed* (about 35% selected a rating of 2) and *disagreed* (about 29% selected a rating of 4) with the statement. Nearly 24% selected the *neutral* rating (rating of 3). This item did not ask participants if they had difficulty refocusing, so the differences in ratings may stem from other types of problems (i.e., obstruction of the view) that participants encountered when alternating their view between the VIEW™ Display and other objects in the room.

Participants were asked to indicate their agreement with the statement: I *had trouble orienting myself with respect to maps portrayed on the display surface.* Only one participant *agreed* (rating of 2), and nearly 47% of the participants *disagreed* (rating of 4) or *strongly disagreed* (rating of 5) with the statement. These data provide no evidence that maintaining orientation with respect to maps portrayed on a tactical information display is made more difficult by a head-mounted display.

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[2] An earlier section of this report discussed the responses to the item that asked participants if they could move their head as fast as they wanted without the helmet moving on their head.

There were wide differences among participants in their agreement with the statement: *I had trouble seeing and understanding tactical graphics portrayed on the display surface.* About 41% of the participants *strongly agreed* (rating of 1) or *agreed* (rating of 2) with this statement. And yet, about 53% *disagreed* (rating of 4) or *strongly disagreed* with the statement (rating of 5). The lack of agreement on this item probably was the result of differences in participants' interpretation. The intent of the item was to determine whether or not tactical graphics could be seen well enough to be understood, individually and collectively. However, it is probable that the participants who *agreed* with the statement responded in terms of the difficulties they encountered in "seeing" the graphics. Conversely, the participants who *disagreed* with the statement were indicating that they encountered no difficulty in "understanding" graphics that they were able to see. This interpretation is consistent with data presented earlier indicating that participants encountered difficulty discriminating alphanumeric characters and point symbols.

Simulator Sickness Symptoms

Item 28 asked participants to use a 3-point rating scale to indicate the severity of each of a set of simulator sickness symptoms experienced while wearing the VIEW™ Display. A rating of 1 indicated that the symptom was not experienced. A ratings of 2 or 3 were used was the symptom was experienced. A rating of 2 was used when the symptom was *mild*, and a rating of 3 was used when the symptom was *severe*. Shown below are the percentages of participants who indicated that the simulator symptoms were *not* experienced (rating of 1).

- Headache (78.6%)
- Eye Strain (66.7%)
- Nausea (93.3%)
- Unsteadiness or Loss of Balance (93.3%)
- Irritability (93.3%)

Of the participants who experienced a simulator sickness symptom, only two indicated that the symptom was severe (rating of 3). One participant reported experiencing severe eyestrain, and one participant reported experiencing severe irritability. In the latter case, it is not known whether the severe irritability was due to the VIEW™ Display or to the requirement to serve as a participant in the evaluation.

Potential Utility of the VIEW™ Display

Participants were asked if they thought that the utility of the VIEW™ Display was sufficient to justify further work to assess its value for use in a ground-based TOC (Item 29) and an airborne TOC (Item 30). With only one exception, participants answered affirmatively to both questions. One participant answered "no" on Item 29, indicating his opinion that the potential was not great enough to justify further work to assess the VIEW™ Display's utility in a ground-based TOC.

Potential Design Improvements

The last item on the questionnaire (Item 31) was an open-ended item that asked participants to list design changes that, in their opinion, would increase the usability and/or utility of the VIEW™ Display. Thirteen participants listed one or more potential design changes. Nine of the participants recommended an increase in display resolution. Three participants recommended each of the following design changes:

- Decrease the weight and improve the weight distribution of the VIEW™ Display;
- Stabilize the VIEW™ Display's image such that small head movements do not cause excessive image movement when the user has zoomed-in as far as possible on an image; and
- Provide the capability to flip the display up when the VIEW™ Display is not in use (these participants were unaware that the VIEW™ Display has this capability).

The design changes listed below were recommended by only one participant in Item 31. However, the last item listed, the need for a pointer, was mentioned by at least five other participants in their responses to other questionnaire items.

- provide an improved method for selecting display input (other than head rotation or use of mouse),
- provide for improved mobility in the TOC, and
- provide each staff member with a unique pointer.

Discussion

A questionnaire is not a suitable vehicle for conducting an in-depth evaluation of the utility and usability of devices such as the VIEW™ Display System. However, questionnaire responses by knowledgeable participants serve to identify potential problems that should be the focus of an in-depth evaluation. Despite participants' limited experience with the VIEW™ Display, their responses provide useful insights about the presence (or absence) of the types of problems that were anticipated. The main insights are discussed in the following paragraphs.

Most participants agreed that (a) the helmet adjustments can be accomplished easily and quickly, (b) only mild discomfort is caused by the helmet's weight or unequal weight distribution, and (c) the helmet's position on the head remains reasonably stable with normal head movements. In short, the participants' responses provide no evidence that the VIEW™ Display's utility or usability are seriously degraded by helmet adjustments, weight, weight distribution, or stability on the head. It is possible that helmet weight, weight distribution, stability, or some combination of these may be a problem in an airborne environment. Additional research is required to determine whether or not helmet movement would be a problem in an airborne environment. It is unlikely that the acceleration forces caused by helicopter movement would be considerably greater than the forces caused by rapid head movements. However, it is possible that vibration could be a problem. That is, even if the helmet remained stationary on the

head, the display imagery would appear blurred if the displays did not vibrate at the same frequency as the wearer's head.

Responses to several different questionnaire items indicated that participants sometimes found it difficult to discriminate alphanumeric characters and symbols, particularly point symbols. Most participants identified inadequate display resolution as the primary cause of the difficulty they encountered in discriminating alphanumeric characters and symbols. There was no evidence that other design attributes (i.e., brightness, contrast, color rendition) degraded image quality enough to seriously influence the discriminability of displayed features. Of course, the amount of display resolution that is needed is partly dependent on both the size of display and the size of the viewing area that is required by the user. As a consequence, increasing display resolution is not the only way to increase users' ability to discriminate displayed features.

Participants were divided in their assessment of the use of head movements to select the display input and to zoom-in and zoom-out on a displayed feature. However, a substantial number of participants indicated that a mouse was a better way to select and zoom than head movements. The dissatisfaction with the use of head movements was greatest for the zoom function. Participants' responses to open end questions indicated that their dissatisfaction with zooming by head movement was at least partly due to the image instability that occurs when the zoom is at or near maximum magnification.

Although a mouse was considered by many participants to be an easier way to select and zoom than head movements, this preference does not indicate that the use of head movements is considered excessively difficult. It should also be acknowledged that the preference for the mouse may reflect the fact that the participants have had far more experience using a mouse than using head movements to drive a displayed image.

Few participants indicated that the VIEW™ Display made it substantially easier to perform information-processing tasks. However, this finding must be interpreted with caution. At the time the participants completed the questionnaire, they had had little time to practice using the VIEW™ Display, and no participant was involved in command and control activities during the time they wore the VIEW™ Display. Furthermore, participants' judgments about the ease of using the VIEW™ Display to perform tasks may have been influenced by the difficulty they encountered in discriminating displayed features. For these reasons, the participants' responses cannot be taken as a valid measure of the extent to which the VIEW™ Display influenced the ease of performing information-processing tasks.

Most participants indicated that the cable attached to the helmet seriously restricts their mobility but does not cause excessive movement of the helmet on the head.

Looking under or around the displays to gain visual access to other information in the TOC was considered to be a problem by some but not all participants.

Because of possible misinterpretation of questionnaire items, the responses are not considered to be a valid indicator of whether or not participants encountered difficulty in (a) alternating their view between the VIEW™ Display and other objects in the TOC, or (b) seeing and understanding tactical graphics. However, it is clear that the participants did not encounter any difficulty orienting themselves with respect to the maps portrayed on the VIEW™ Display.

Participants' limited exposure prevented them from providing reliable information about the ease of offset viewing, the effect of high and low ambient illumination, the effect of glare, and the problems in interacting with other staff members when wearing the VIEW™ Display.

A small number of participants reported experiencing mild headaches and mild eyestrain during the time they wore the VIEW™ Display. However, participants' responses provide no evidence that wearing the VIEW™ Display induces severe or even mildly disabling simulator sickness in a ground-based environment. Further research is required to determine whether wearing the VIEW™ Display in an airborne environment will increase the incidence and/or severity of simulator sickness.

Participants were nearly unanimous in their belief that the VIEW™ Display has sufficient potential to justify further work to evaluate its utility and usability in both a ground-based and an airborne environment.

Conclusions

The findings discussed above are considered adequate to support the general conclusions listed below.

- A head-mounted display is a feasible and potentially effective way to display tactical information to the battle staff members who occupy a TOC.
- The VIEW™ Display System has no fundamental design shortcomings that make it unusable in a ground-based environment.
- An increase in the VIEW™ Display's resolution would increase its utility, usability, and user acceptance.
- Additional research is needed to fully evaluate the VIEW™ Display's utility and usability in both a ground-based and an airborne environment.
- A more in-depth evaluation must employ participants who have been trained on the capabilities of the VIEW™ Display and have had sufficient practice to become proficient in its use.

Appendix A

Questionnaire Used to Perform the Preliminary Assessment of the Kaiser VIEW™ Display

PRELIMINARY ASSESSMENT OF THE
KAISER VIEW™ DISPLAY SYSTEM

1. Name ______________________________ 2. Duty phone ______________

3. Approximately how long did you wear the Kaiser VIEW™ helmet and how long did you view an active Kaiser VIEW™ display?
   _______ Total minutes wearing the helmet
   _______ minutes viewing an active display

4. Check the workstation displays you viewed with the Kaiser VIEW™ display.
   [ ] ASAS
   [ ] JSTARS
   [ ] MCS/P
   [ ] AFATDS
   [ ] AMD W/S
   [ ] FAADEO
   [ ] CSSCS
   [ ] UAV
   [ ] Other (specify) ______________________________

5. Check the Kaiser VIEW™ display features and viewing conditions that you examined at least briefly.
   [ ] Selecting different workstation displays by moving head
   [ ] Selecting different workstation displays by moving a mouse
   [ ] Zooming in on a workstation display by moving head
   [ ] Zooming in on a workstation display by moving a mouse
   [ ] Offset viewing (display is located left or right of frontal plane)
   [ ] Viewing display while moving about the TOC
   [ ] Viewing display in low ambient illumination
   [ ] Viewing the display in high ambient illumination
   [ ] Interacting with a fellow staff member about a specific feature appearing on a workstation display
   [ ] Other (specify) ______________________________

6. When wearing the VIEW™ helmet, were you engaged in any command and control activities that required you to perform tasks or make decisions?
   [ ] No
   [ ] Yes
   If yes, briefly describe the activities you were engaged in while wearing the VIEW™ display. _______
   ____
   ____
   ____
   ____
   ____

The following items ask you to express your opinions about the comfort of the VIEW™ helmet and the ease of donning and helmet and adjusting the display.

7. Check the box that corresponds with your opinion about the ease of making each of the following types of adjustments.

	Very Easy		Moderately Difficult		Very Difficult
Adjusting the helmet to fit your head	[ ]	[ ]	[ ]	[ ]	[ ]
Fore/aft adjustment of displays	[ ]	[ ]	[ ]	[ ]	[ ]
Vertical adjustment of displays	[ ]	[ ]	[ ]	[ ]	[ ]
Interpupillary adjustment of displays	[ ]	[ ]	[ ]	[ ]	[ ]

8. About how long did it take you to successfully complete each of the following adjustments?
   _________ Minutes to adjust helmet to fit head
   _________ Minutes to adjust fore/aft position of displays
   _________ Minutes to adjust vertical position of displays
   _________ Minutes to adjust interpupillary distance

9. Did you encounter any difficulty adjusting the displays to a position where the display images were in clear focus?
   [ ] No
   [ ] Yes

10. Did you encounter any difficulty adjusting the helmet so that the weight was about evenly distributed on your head?
    [ ] No
    [ ] Yes
    If yes, indicate below the nature of the unequal distribution of weight.
    [ ] too much weight in front (front heavy)
    [ ] too much weight in rear (rear heavy)
    [ ] too much weight on right-hand side (right heavy)
    [ ] too much weight on left-hand side (left heavy)

11. Check the box that corresponds with the type and degree of discomfort you were experiencing at the time you removed the VIEW™ helmet.

	No Discomfort		Moderate Discomfort		Severe Discomfort
General discomfort where helmet touched head	[ ]	[ ]	[ ]	[ ]	[ ]
Discomfort at only a few spots on head	[ ]	[ ]	[ ]	[ ]	[ ]
Neck discomfort from weight on head	[ ]	[ ]	[ ]	[ ]	[ ]
Shoulder discomfort from weight on head	[ ]	[ ]	[ ]	[ ]	[ ]

12. When you moved your head or body position, did the cable attached to the rear of the helmet sometimes cause the helmet to move on your head?
    [ ] No
    [ ] Yes

13. Check the box that corresponds with the amount the helmet moved on your head as a result of your head movements.

	No Movement		Small Movement		Large Movement
Lateral head rotation (side-to-side rotation)	[ ]	[ ]	[ ]	[ ]	[ ]
Vertical head rotation (up-down rotation)	[ ]	[ ]	[ ]	[ ]	[ ]
Fore and aft movement (no head rotation)	[ ]	[ ]	[ ]	[ ]	[ ]

14. Did you wear eyeglasses at the time you used the VIEW™ display?
    [ ] No
    [ ] Yes
    If yes, was the clearance for your eyeglasses adequate?
    [ ] Yes
    [ ] No

The following items ask you to express your opinions about resolution and image quality of the VIEW™ display. Of particular interest is how well you could see characters (letters and numbers), point symbols, and linear symbols on the VIEW™ display.

15. Check your degree of agreement with each of the following statements.

	Strongly Agree		Neutral		Strongly Disagree
In order to discriminate a character (letter or number), I often had to zoom in on the character more than I wanted.	[ ]	[ ]	[ ]	[ ]	[ ]
In order to discriminate a point symbol, I often had to zoom in on the symbol more than I wanted.	[ ]	[ ]	[ ]	[ ]	[ ]
In order to discriminate a linear symbol, I often had to zoom in on the symbol more than I wanted.	[ ]	[ ]	[ ]	[ ]	[ ]
When characters and symbols were large enough to be legible, I could not see as much of the total display as I wanted to see.	[ ]	[ ]	[ ]	[ ]	[ ]
Objects on the display were difficult to discriminate because of inadequate contrast between the objects and the background.	[ ]	[ ]	[ ]	[ ]	[ ]
It was sometimes difficult to discriminate the color of objects.	[ ]	[ ]	[ ]	[ ]	[ ]

16. Was it substantially more difficult to discriminate letters, numbers, or symbols when you viewed the display under high ambient illumination?
    [ ] No
    [ ] Yes
    [ ] Did not view display under high ambient illumination

17. Did stray light (glare) sometimes make it more difficult to discriminate letters, numbers, or symbols?
    [ ] No
    [ ] Yes
    [ ] Did not view display under conditions that would produce glare

18. Was the display free of spatial distortion? For example, did straight lines appear straight and did square objects appear square throughout the display?
    [ ] No
    [ ] Yes

19. Was the display free of color distortion? For example, did objects of the same color appear the same (color) throughout the display?
    [ ] No
    [ ] Yes

20. Did the displayed images appear to be in sharp (vs. Fuzzy) focus?
    [ ] No
    [ ] Yes

21. Was the focus of displayed images equally sharp throughout the entire display surface?
    [ ] No
    [ ] Yes

22. Did the sharpness of displayed images change (become more or less sharp) during the time that you used the VIEW™ display?
    [ ] No
    [ ] Yes

23. Did you notice any type of video noise or other image aberrations that degraded the clearness or legibility of the displayed images?
    [ ] No
    [ ] Yes
    If yes, please describe what you observed. ____
    ____
    ____
    ____

The following items ask your to express you opinions about the usability and the utility of the VIEW™ display system.

24. Check your degree of agreement with each of the following statements about the VIEW™ display system.

	Strongly Agree		Neutral		Strongly Disagree
The cable attached to the rear of the helmet constrained my freedom to move (walk) around the TOC.	[ ]	[ ]	[ ]	[ ]	[ ]
I was able to view other things I needed to see in the TOC by looking under the display or to the left or right of the display.	[ ]	[ ]	[ ]	[ ]	[ ]
I was able to move my head as fast I wanted without the helmet moving on my head.	[ ]	[ ]	[ ]	[ ]	[ ]
I had trouble alternating my view between the displayed images and objects in the room.	[ ]	[ ]	[ ]	[ ]	[ ]
I had trouble orienting myself with respect to maps portrayed on the display surface.	[ ]	[ ]	[ ]	[ ]	[ ]
I had trouble seeing and understanding tactical graphics portrayed on the display surface.	[ ]	[ ]	[ ]	[ ]	[ ]

25. Check the box that corresponds with your opinion about the ease of performing each of the following tasks. (Write N/A if you did not attempt to perform the task.)

	Very Easy		Moderately Difficult		Very Difficult
Select different tactical displays by rotating head	[ ]	[ ]	[ ]	[ ]	[ ]
Zoom in/out on a display by fore/aft head movements	[ ]	[ ]	[ ]	[ ]	[ ]
Select different tactical displays with a mouse	[ ]	[ ]	[ ]	[ ]	[ ]
Zoom in/out on a display with a mouse	[ ]	[ ]	[ ]	[ ]	[ ]

26. Check the box that corresponds with your opinion about whether the VIEW™ display makes the following tasks easier or more difficult (in comparison with the displays that are now used in the digital TOC).

	Much Easier		About the Same		Much More Difficult
Obtain information quickly	[ ]	[ ]	[ ]	[ ]	[ ]
Convert data to information	[ ]	[ ]	[ ]	[ ]	[ ]
Maintain situation awareness	[ ]	[ ]	[ ]	[ ]	[ ]
Share information with other staff members	[ ]	[ ]	[ ]	[ ]	[ ]

27. Did you encounter any difficulty discussing a displayed feature with a fellow staff member because you were unable to point to the feature?
[ ] No
[ ] Yes
If yes, please describe your ideas about how to overcome this problem. ______________________
____
____

28. Check below the type and severity of any simulator sickness symptoms you experienced during or following the time you wore the VIEW™ display.

	None	Mild	Severe
Headache	[ ]	[ ]	[ ]
Eye Strain	[ ]	[ ]	[ ]
Nausea	[ ]	[ ]	[ ]
Unsteadiness or Loss of Balance	[ ]	[ ]	[ ]
Irritability	[ ]	[ ]	[ ]
Other (specify) ______________________	[ ]	[ ]	[ ]
Other (specify) ______________________	[ ]	[ ]	[ ]

29. Do you believe that the potential utility of the VIEW™ display is great enough to justify further work to assess its value for use in a ground-based digital TOC?
[ ] No
[ ] Yes

30. Do you believe that the potential utility of the VIEW™ display is great enough to justify further work to assess its value for use in an airborne digital TOC (with associated vibration and buffeting)?
[ ] No
[ ] Yes

31. Do you believe that there are feasible design changes that would increase the usability and/or utility of the VIEW™ display (for use in a digital TOC)?
[ ] No
[ ] Yes
If yes, please explain the design changes that you believe would be beneficial. ________________
____
____
____
____
____
____

32. Other comments: ____
____
____
____

Appendix B

Tabulations of Questionnaire Responses

Appendix B
Tabulations of Questionnaire Responses

The tables in this appendix contain detailed tabulations of the responses to each questionnaire item. The content and organization of the data tables are described below.

The item number is shown in the left-hand column. The second column from the left lists the question asked and, when appropriate, the response alternatives participants were required to consider. The contents of the remaining columns vary, depending on the type of questionnaire item and the type of responses participants were required to make.

For items that required a yes/no response, the table shows the number and percentage of participants who selected each alternative. When all participants selected the same alternative (all yes or all no responses), the table shows only the number of participants who responded to the item. Responses to checklist items were tabulated in much the same way as responses to yes/no items. That is, the tables show the number and percentage of participants who checked each alternative. Tabulations for rating-scale items show the number of participants who selected each rating-scale value. Percentages are not shown for rating-scale items, but can be easily calculated with the data shown.

A few items required participants to enter a number. For such items, the responses are presented in the form of a frequency distribution. For example, a frequency distribution of time (in minutes) was used to tabulate the responses to the item that requested participants to record the time required to complete the helmet adjustments.

All percentage values are based on the number of participants who responded to an item rather than the total number of participants. For example, if only 15 of the 17 participants responded to an item, the denominator in the percentage computation was 15 rather than 17.

Three descriptive statistics are shown for each rating item: the *mean* rating, the *standard deviation* (SD), and the *median* rating. The same three descriptive statistics are shown for items that required participants to enter a number (e.g., time). In addition, inferential statistics are shown for selected items. All inferential statistics are based on the Sign Test, a distribution-free (nonparametric) test that is described in nearly every statistics textbook.[3]

One Sign Test was used to test the null hypothesis that the true median differs from a prescribed value. For some items the Sign Test yielded the probability that the true median is equal to or less than 2.5 [$p(Md \leq 2.5)$]. For other items, the Sign Test was used to test the null hypothesis that the median is equal to or greater than 3.5 [$p(Md \geq 3.5)$]. For yes/no items, the Sign Test was used to test the null hypothesis that the yes and no occur with equal frequency [$p(\#Yes = \#No)$].

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[3] For example, see Guilford, J.P., and Fructer, B. (1976). *Fundamental statistics in psychology and education.* McGraw Hill: New York.

3	**Minutes Wearing Helmet**	8	10	15	20	30	60	90	**MEAN**	**SD**	**MEDIAN**
	Number of Respondents	1	5	5	2	2	1	1	22.5	21.4	15.0
	Minutes Viewing Active Display	7	8	10	15	25	30	80	**MEAN**	**SD**	**MEDIAN**
	Number of Respondents	2	1	6	3	1	2	1	18.3	18.1	10.0

4	**Check the workstation displays you viewed with the Kaiser VIEW Display.**	**N**	**%**
	ASAS	16	94.1%
	JSTARS	7	41.2%
	MCS/P	15	88.2%
	AFATDS	6	35.3%
	AMD W/S	8	47.1%
	FAADEO	3	17.7%
	CSSCS	2	11.8%
	UAV	11	64.7%

5	**Check the Kaiser Display features and viewing conditions that you examined at least briefly.**	**N**	**%**
	Selecting different workstation displays by moving head	17	100.0%
	Selecting different workstation displays by moving a mouse	15	88.2%
	Zooming in on a workstation display by moving head	16	94.1%
	Zooming in on a workstation display by moving a mouse	12	70.6%
	Offset viewing (display is located left or right of frontal plane)	8	47.1%
	Viewing display while moving about the TOC	3	17.7%
	Viewing display in low ambient illumination	6	35.3%
	Viewing display in high ambient illumination	2	11.8%
	Interacting with a fellow staff member about a specific feature appearing on a workstation display	6	35.3%

		NO	
		N	%
6	When wearing the VIEW helmet, were you engaged in any command and control activities that required you to perform tasks or make decisions?	17	100%

		1	2	3	4	5				
7	Check the box that corresponds with your opinion about the ease of making each of the following types of adjustments.	VERY EASY		MOD. EASY		VERY DIFFICUL T	MEAN	SD	MEDIAN	p(Md≥2.5)
	Adjusting the helmet to fit your head	13	4	0	0	0	1.2	0.44	1.0	<.001
	Fore/aft adjustment of displays	8	8	0	1	0	1.6	0.79	2.0	<.001
	Vertical adjustment of displays	6	11	0	0	0	1.6	0.49	2.0	<.001
	Interpupillary adjustment of displays	8	8	1	0	0	1.6	0.60	2.0	<.001

8	About how long did it take you to successfully complete each of the following adjustments?	<1 min	1 min	>1 min	MEAN	SD	MEDIAN
	Minutes to adjust helmet to fit head	9	5	3	0.87	0.70	0.50
	Minutes to adjust fore/aft position of displays	6	8	3	0.97	0.71	1.00
	Minutes to adjust vertical position of displays	5	6	5	0.97	0.64	1.00
	Minutes to adjust interpupillary distance	8	7	2	2.18	1.13	1.00

		YES		NO	
		N	%	N	%
9	Did you encounter any difficulty adjusting the displays to a position where the display images were in clear focus?	6	40%	9	60%

		YES		NO	
		N	%	N	%
10	Did you encounter any difficulty adjusting the helmet so that the weight was about evenly distributed on your head?	3	18%	15	88%

10A	If yes, indicate below the nature of the unequal distribution of weight.	N
	Too much weight in front (front heavy)	3
	Too much weight in rear (rear heavy)	0
	Too much weight on right-hand side (right heavy)	0
	Too much weight on left-hand side (left heavy)	0

11	Check the box that corresponds with the type and degree of discomfort you were experiencing at the time you removed the View helmet.	1 No Discomfort	2	3 Mod. Discomfort	4	5 Severe Discomfort	MEAN	SD	MEDIAN	p(Md≥2.5)
	General discomfort where helmet touched head	9	4	3	0	0	1.63	0.81	1.0	.011
	Discomfort at only a few spots on head	8	8	1	0	0	1.59	0.62	2.0	<.001
	Neck discomfort from weight on head	8	5	2	0	0	1.60	0.73	1.0	.004
	Shoulder discomfort from weight on head	11	3	1	0	0	1.33	0.62	1.0	.001

		YES		NO	
		N	%	N	%
12	When you moved your head or body position, did the cable attached to the rear of the helmet sometimes cause the helmet to move on your head?	10	59%	7	41%

13	Check the box that corresponds with the amount the helmet moved on your head as a result of your head movements.	1 No Movement	2	3 Small Movement	4	5 Large Movement	MEAN	SD	MEDIAN	p(Md≥2.5)
	Lateral head rotation	4	3	8	0	0	2.27	0.88	3.0	.5
	Vertical head rotation	4	3	7	1	0	2.33	0.98	3.0	.5
	Fore and aft movement	6	3	4	0	0	1.85	0.90	2.0	.13

		YES
14	**Did you wear eyeglasses at time you used the VIEW display?**	4
	If yes, was the clearance for your eyeglasses adequate?	4

		1	2	3	4	5				
15	**Check your degree of agreement with each of the following statements.**	Strongly Agree		Neutral		Strongly Disagree	MEAN	SD	MEDIAN	p(Md≥2.5)
	In order to discriminate a character (letter or number), I often had to zoom in on the character more than I wanted.	8	8	1	0	0	1.59	0.62	2.0	<.001
	In order to discriminate a point symbol, I often had to zoom in on the symbol more than I wanted.	6	7	4	0	0	1.88	0.78	2.0	.025
	In order to discriminate a linear symbol, I often had to zoom in on the symbol more than I wanted.	3	4	9	1	0	2.47	0.87	3.0	.50
	When characters and symbols were large enough to be legible, I could not see as much of the total display as I wanted to see.	3	4	8	1	1	2.59	1.06	3.0	.315

										p(Md≥3.5)
15 cont'd	Objects on the display were difficult to discriminate because of inadequate contrast between the objects and the background.	1	2	7	5	2	3.29	1.05	3.0	.006
	It was sometimes difficult to discriminate the color of objects.	2	1	2	8	4	3.65	1.27	4.0	.006

		YES	NO	DNR*
16	**Was it substantially more difficult to discriminate letters, numbers, or symbols when you viewed the display under high ambient illumination?**	0	1	16
17	**Did stray light (glare) sometimes make it more difficult to discriminate letters, numbers, or symbols?**	2	1	14

*Did not respond

		Y ES		N O		
		N	%	N	%	p(#Y=#N)
18	**Was the display free of spatial distortion?**	15	88.2%	2	11.8%	.001
19	**Was display free of color distortion?**	15	88.2%	2	11.8%	.001
20	**Did the displayed images appear to be in sharp (vs. fuzzy) focus?**	5	29.4%	12	70.6%	.072

21	**Was the focus of displayed images equally sharp throughout the entire display surface?**	12	70.6%	5	29.4%	.072
22	**Did the sharpness of displayed images change (become more or less sharp) during the time you used the VIEW display?**	2	11.8%	15	88.2%	.001
23	**Did you notice any type of video noise or other image aberrations that degraded the clearness or legibility of the displayed images?**	2	11.8%	14	82.4%	.002

		1	2	3	4	5				
24	**Check your degree of agreement with each of the following statements about the VIEW display system.**	Strongly Agree		Neutral		Strongly Disagree	**MEAN**	**SD**	**MEDIAN**	**p(Md≥2.5)**
	The cable attached to the rear of the helmet constrained my freedom to move (walk) around the TOC.	3	4	8	0	0	2.33	0.82	3.0	.50
	I was able to view other things I needed to see in the TOC by looking under the display or to the left or right of the display.	3	6	4	2	2	2.65	1.27	2.0	.50
	I was able to move my head as fast as I wanted without the helmet moving on my head.	0	9	3	4	1	2.82	1.01	2.0	.50
	I had trouble alternating my view between the displayed images and objects in the room.	1	6	4	5	1	2.94	1.01	3.0	.50

										p(Md≥3.5)
24 cont'd	I had trouble orienting myself with respect to maps portrayed on the display surface.	0	1	8	6	2	3.53	0.8	3.0	.001
	I had trouble seeing and understanding tactical graphics portrayed on the display surface.	2	5	1	8	1	3.05	1.24	4.0	.315

		1	2	3	4	5				
25	**Check the box that corresponds with your opinion about the ease of performing each of the following tasks.**	Very Easy		Mod. Difficult		Very Difficult	**MEAN**	**SD**	**MEDIAN**	**p(Md≥2.5)**
	Select different tactical displays by rotating head	4	7	5	0	1	2.24	1.03	2.0	.166
	Zoom in/out on a display by fore/aft head movements	4	2	6	4	0	2.63	1.15	3.0	.166
	Select different tactical displays with a mouse	8	8	0	0	0	1.50	0.52	1.5	<.001
	Zoom in/out on a display with a mouse	6	8	0	0	0	1.57	0.51	2.0	<.001

		1	2	3	4	5				
26	**Check the box that corresponds with your opinion about whether the VIEW display makes the following tasks easier or more difficult.**	Much Easier		About the Same		Much More Difficult	**MEAN**	**SD**	**MEDIAN**	**p(Md≥2.5)**
	Obtain information quickly	0	3	5	4	1	3.23	0.93	3.0	.046
	Convert data to information	0	2	7	2	1	3.17	0.84	3.0	.019
	Maintain situational awareness	0	4	3	3	2	3.25	1.14	3.0	.194
	Share information with other staff members	0	3	3	3	2	3.36	1.12	3.0	.113

		YES		NO		
		N	**%**	**N**	**%**	**p(#Y=#N)**
27	**Did you encounter any difficulty discussing a displayed feature with a fellow staff member because you were unable to point to the feature?**	6	54.5%	5	45.5%	.5

28	**Check below the type and severity of any simulator sickness symptoms you experienced during or following the time you wore the VIEW display.**	None	Mild	Severe
	Headache	11	4	0
	Eye Strain	10	4	1
	Nausea	14	1	0
	Unsteadiness or Loss of Balance	14	1	0
	Irritability	13	0	1

		YES		NO		
		N	**%**	**N**	**%**	**p(#Y=#N)**
29	**Do you believe that the potential utility of the VIEW display is great enough to justify further work to assess its value for use in a ground-based digital TOC?**	16	94.1%	1	5.9%	<.001
30	**Do you believe that the potential utility of the VIEW display is great enough to justify further work to assess its value for use in an airborne digital TOC (with associated vibration and buffeting)?**	16	100.0%	0	0.0%	<.001
31	**Do you believe that there are feasible design changes that would increase the usability and/or utility of the VIEW display (for use in a digital TOC)?**	13	92.9%	1	7.1%	<.001